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DESCRIPTION

FRICTION ROLLER TRANSMISSION

Technical Field

The present invention relates to a friction roller transmission for transmitting torque while changing speed by means of a friction roller.

Background Art

In Japanese Patent Application Laid-Open Nos. 2002-349653 and 2003-28251 that have been filed and laid open prior to this patent application, there is disclosed a friction roller transmission characterized in that:

a first roller and a second roller are disposed on two parallel shafts that are separated from each other in such a way that the rollers are not in contact with each other, the shafts being at the center of the respective rollers;

a third roller and a fourth roller that are in contact with both the first and the second rollers are disposed between the first roller and the second roller and on opposite sides with respect to the line connecting the center of the first roller and the center of the second roller; and

the angle formed by the tangential line of the first roller and the third roller and the tangential line of the second roller and the third roller and the angle formed by the tangential line of the first roller and the fourth roller and the tangential line of the second roller and the fourth roller are designed to be smaller than or equal to twice the respective angles of friction that are determined from the coefficients of friction between the respective rollers.

With the above features, it is possible to constitute a transmission path from the first roller to the third roller and then to the second roller, and another transmission path from the first roller to the fourth roller and then to the second roller, thereby allowing both the forward and backward rotations in a backlash-free frictional roller transmission. It is also possible to minimize an increase in the working torque by generating a roller pressing power in accordance with the transmitted torque, whereby the efficiency can be improved, particularly in the low transmitted torque range. In addition, since the rollers for power transmission are respectively provided for the rotation directions in such a way as to be in contact to the rollers, torque transmission can be made possible without delay and without generating a slapping sound even

when the direction of rotation is reversed.

A more specific description will be made in the following under an assumption that the first roller is the input side roller.

When the first roller is rotated clockwise (in the CW direction), since the tangential line of the third roller and the first roller and the tangential line of the third roller and the second roller forms an angle smaller than or equal to twice the friction angle, each contact angle is not larger than the friction angle. Accordingly, relative slippage of the third roller and the first roller does not occur at their contact portion. Thus, a rotational force of the counterclockwise direction (in the CCW direction) is transmitted to the third roller by this tangential force in the direction in which the third roller is brought closer to the first roller.

At the contact portion between the third roller and the second roller also, since the tangential line of the third roller and the first roller and the tangential line of the third roller and the second roller forms an angle smaller than or equal to twice the friction angle, each contact angle is not larger than the friction angle. Accordingly, relative slippage of the third roller and the second roller does not occur at their contact portion. Thus, a tangential force acts on the second roller from the

third roller, so that the second roller receives a rotational force in the CW rotation direction. As the reaction, the third roller receives a tangential force in the opposite direction. This tangential force is in such a direction that the third roller is brought closer to the second roller.

The tangential forces acting on the third roller is a force biasing the third roller toward the first and the second rollers, and therefore, a pressing force corresponding to the tangential force transmitted or the torque can be obtained. The operation of the fourth roller is the same as the operation of the third roller except for the direction of rotation, and the description thereof will be omitted.

The aforementioned patent documents teach to provide backup rollers that are in contact with the third and the fourth rollers to restrict displacement of the third and the fourth rollers to a predetermined amount. The backup roller is, for example, a rolling bearing with an outer ring serving as the contact surface.

By restricting displacement of the third and the fourth rollers to a predetermined amount by means of the backup rolling bearings that constitute the backup rollers, getting-over of the third and the fourth rollers are prevented so that a torque more

than a predetermined value cannot be transmitted.

In the arrangements disclosed in the aforementioned patent documents, the position of the backup rolling bearings that constitute the backup rollers is fixed, and the maximum transmissible torque is restricted by them. Since the maximum transmissible torque is determined by the surface pressure between the rollers, the radial stiffness of the input and output rolling bearings for rotatably supporting the first and the second rollers is a factor on which the surface pressure depends. In the prior arts, the radial stiffness is assumed to be a fixed value in calculation. However, there are variations in the radial stiffness of the bearings, and there is a problem that the intended maximum transmissible torque is not achieved.

Disclosure of the Invention

The present invention has been made in view of the above-described circumstances, and has as an object to provide a friction roller transmission in which the maximum transmissible torque can be determined as desired and failure of the transmission path due to excessive torque transmission can be prevented.

To achieve the above object, according to the present invention, there is provided a friction

roller transmission comprising:

a first roller and a second roller disposed on two parallel shafts that are separated from each other in such a way that the rollers are not in contact with each other, the shafts being at the center of the respective rollers;

a third roller and a fourth roller that are in contact with both the first and the second rollers disposed between said first roller and said second roller, the third roller and the fourth roller being opposite to a line connecting the center of the first roller and the center of the second roller; and

backup bearings that are in contact with said third and said fourth rollers respectively to restrict displacement amount of said third roller and said fourth roller,

characterized in that the position of said backup bearings can be adjusted.

As per the above, in the friction roller transmission according to the present invention, backup bearings for restricting displacement of the third and the fourth rollers to a predetermined amount is provided, and the position of the backup bearings can be adjusted. Thus, it is possible to achieve the intended maximum transmissible torque and to prevent failure of the transmission path due to excessive torque transmission from occurring.

In the friction roller transmission according to the present invention, it is preferred that in said backup bearing, a bearing mount portion and a shaft that constitutes a base for mounting on a plate be eccentric to each other.

Brief Description of the Drawings

Fig. 1A is a side view of a friction roller transmission that constitutes a basic structure according to the present invention.

Fig. 1B is a schematic perspective view of the friction roller transmission shown in Fig. 1A.

Fig. 2A is a side view of the friction roller transmission that constitutes the basic structure according to the present invention, showing a transmission path from the first roller to the fourth roller and then to the second roller.

Fig. 2B is a side view of the same kind showing a transmission path from the first roller to the third roller and then to the second roller.

In Figs. 3A to 3C that show a friction roller transmission according to an embodiment of the present invention, Fig. 3A is a partly cut-away front view, Fig. 3B is a cross sectional view taken along line b-b in Fig. 3A, and Fig. 3C is a cross sectional view taken along line c-c in Fig. 3B.

Fig. 4 is an exploded cross sectional view of

the friction roller transmission shown in Figs. 3A to 3C.

Fig. 5 is an exploded perspective view of the friction roller transmission shown in Figs. 3A to 3C.

Fig. 6A is a cross sectional view of a backup rolling bearing serving as a backup roller including a mounting bolt shaft.

Fig. 6B is a side view thereof.

Fig. 7 is a perspective view of the backup rolling bearing serving as a backup roller including a mounting bolt shaft.

In Figs. 8A to 8C showing a friction roller transmission according to a modification of the aforementioned embodiment of the present invention, Fig. 8A is a partly cut-away front view, Fig. 8B is a cross sectional view taken along line b-b in Fig. 8A, and Fig. 8C is a cross sectional view taken along line c-c in Fig. 8B.

Embodiment of the Invention

In the following, a friction roller transmission according to a preferred embodiment of the present invention will be described with reference to the drawings.

(Basic Structure)

Fig. 1A is a side view of a friction roller transmission that constitutes the basic structure

according to the present invention. Fig. 1B is a schematic perspective view of the friction roller transmission shown in Fig. 1A. Fig. 2A is a side view of the friction roller transmission that constitutes the basic structure according to the present invention (illustrating a transmission path from the first roller to the fourth roller and then to the second roller). Fig. 2B is a side view of the same kind (illustrating a transmission path from the first roller to the third roller and then to the second roller).

In this basic structure of the friction roller transmission as shown in Figs. 1A, 1B, 2A and 2B,

a first roller 1 and a second roller 2 are disposed on two parallel shafts that are separated from each other in such a way that the rollers are not in contact with each other, the shafts being at the center of the respective rollers;

a third roller 3 and a fourth roller 4 that are in contact with both the first roller 1 and the second roller 2 are disposed between said first roller 1 and said second roller 2 and on opposite sides with respect to the line connecting the center of the first roller 1 and the center of the second roller 2; and

an angle formed by a tangential line of the first roller 1 and the third roller 3 and a

tangential line of the second roller 2 and the third roller 3 and an angle formed by a tangential line of the first roller 1 and the fourth roller 4 and a tangential line of the second roller 2 and the fourth roller 4 are designed to be smaller than or equal to twice the respective angles of friction that are determined from the coefficients of friction between the respective rollers, the frictional portions thereof being located outside the rollers.

In other words, letting P1 to P4 be the centers of the respective rollers, the rollers are designed in such a way that the sum of the angle formed by the line P1P2 and the line P1P3 (α_1: ∠P2P1P3) and the angle formed by the line P1P2 and the line P2P3 (α_2: ∠P1P2P3) and the sum of the angle formed by the line P1P2 and the line P1P4 (α_3: ∠P2P1P4) and the angle formed by the line P1P2 and the line P2P4 (α_4: ∠P1P2P4) are smaller than or equal to twice the friction angle ($\theta = \tan^{-1}\mu$) as formulated below.

$$\alpha_1 + \alpha_2 \leqq 2\theta$$

$$\alpha_3 + \alpha_4 \leqq 2\theta$$

In cases where the above-described arrangement is adopted, since the friction angle is small, the third roller 3 and the fourth roller 4 are necessarily disposed in an overlapping manner along the axial direction.

By adopting the above-described structure, a

pressing force can be created in accordance with the transmitted torque. Therefore, it is not necessary to apply forces required for frictional transmission, namely forces for pressing the third and the fourth rollers 3 and 4 against the first and the second rollers 1 and 2 respectively. However, it is preferable that weak pressing forces be applied for retaining the initial contact state when the roller is not rotating. Although each roller is composed of one roller, it may be composed of a plurality of rollers.

In the following, the operation of the structure will be described under the assumption that the first roller 1 is the input side roller.

As shown in Figs. 1B and 2B, when the first roller 1 is rotated clockwise (in the CW direction), since the angle formed by the tangential line of the third roller 3 and the first roller 1 and the tangential line of the third roller 3 and the second roller 2 is smaller than or equal to twice the friction angle, the respective contact angles are smaller than or equal to the friction angle. Accordingly, relative slippage between the third roller 3 and the first roller 1 does not occur at their contact portion, and the third roller 3 receives a tangential force from the first roller 1. This tangential force is in such a direction that the

third roller 3 is brought closer to the first roller 1, and the third roller 3 receives a counterclockwise force (in the CCW direction) by this tangential force.

In the contact portion between the third roller 3 and the second roller 2 also, since the tangential line of the third roller 3 and the first roller 1 and the tangential line of the third roller 3 and the second roller 2 form an angle smaller than or equal to the friction angle, the respective contact angles are smaller than or equal to the friction angle. Therefore, relative slippage between the third roller 3 and the second roller 2 does not occur at their contact portion. Accordingly, the second roller 2 receives a tangential force from the third roller 3 and receives a rotational force in the CW direction. As a reaction thereto, a tangential force in the opposite acts on the third roller 3. This tangential force is in such a direction that the third roller 3 is brought closer to the second roller 2.

As per the above, the tangential forces acting on the third roller 3 are in such a direction that the third roller 3 is pressed against the first roller 1 and the second roller 2. Accordingly, a pressing force is created in accordance with the transmitted tangential force or torque.

In this case, as shown in Fig. 2A, slippage does

not occur in the contact portions of the fourth roller 4. Accordingly, the fourth roller 4 receives tangential forces from the first and the second rollers 1 and 2. However, the forces are in such a direction that the fourth roller 4 is brought away from the first and the second rollers 1 and 2, and the fourth roller 4 is only rotating while in contact with the first roller 1 and the second roller 2.

When the rotation of the first roller 1 is reversed and it rotates in the CCW direction as shown in Figs. 1B and 2A, the operation of the fourth roller 4 and the operation of the third roller 3 are switched to each other. In this case, since the fourth roller 4 has been already in contact with the first roller 1 and the second roller 2, the direction of power transmission can be changed smoothly when the direction of rotation is changed.

What is required to enable torque transmission is that each of the third and the fourth rollers 3 and 4 are in contact with the first and the second rollers 1 and 2. To retain the contact state, weak pressing forces for pressing the third and the fourth rollers 3 and 4 against the first and the second rollers 1 and 2 may be applied.

As per the above, according to this basic structure, it is possible to constitute a transmission path from the first roller 1 to the

third roller 3 and then to the second roller 2, and a transmission path from the first roller 1 to the fourth roller 4 and then to the second roller 2 to make forward and backward rotation possible in a backlash-free friction roller transmission (speed-reduction transmission). In addition, since a roller pressing force in accordance with the transmitted torque is created, it is possible to minimize an increase in the working torque. Particularly, it is possible to improve efficiency in the transmission torque range. Moreover, since the rollers that are always in contact are provided for transmitting power in respective rotational directions, torque transmission can be realized without delay and without generating a slapping sound even upon reversal of the rotation direction.

(Embodiment of the Present Invention)

Figs. 3A to 3C show a friction roller transmission (speed-reduction transmission) according to an embodiment of the present invention. Fig. 3A is a partly cut-away front view, Fig. 3B is a cross sectional view taken along line b-b in Fig. 3A, and Fig. 3C is a cross sectional view taken along line c-c in Fig. 3B.

Fig. 4 is an exploded cross sectional view of the friction roller transmission (speed-reduction

transmission) shown in Figs. 3A to 3C. Fig. 5 is an exploded perspective view of the friction roller transmission (speed-reduction transmission) shown in Figs. 3A to 3C.

Fig. 6A is a cross sectional view of a backup rolling bearing serving as a backup roller including a mounting bolt shaft, and Fig. 6B is the side view thereof. Fig. 7 is a perspective view of the backup rolling bearing serving as a backup roller including a mounting bolt shaft.

This embodiment embodies the above-described basic structure, and the arrangement of the first to the fourth rollers 1 to 4, the contact angles and the friction angle are designed to be the same as those in the basic structure.

As shown in Fig. 3A to 3C and Fig. 5, a pair of support plates 11a, 11b are disposed on both sides of a plate-like spacer 10. A plurality of bolts 12 passing through one of the support plates 11a and the plate-like spacer 10 are screwed into screw holes on the other support plate 11b thereby assembling the plate-like spacer 10 and the two support plates 11a, 11b.

Between the plate-like spacer 10 and the pair of support plates 11a, 11b, a pair of ring-shaped sealing members 13, 13 are interposed. The plate-like spacer 10 is made of a light-weight material

such as an aluminum alloy and may be formed by casting such as die casting.

The two support plates 11a and 11b have the same thickness and the same shape. The support plates 11a and 11b respectively have holes for supporting paired bearings 14a and 14b that rotatably support the shaft 1a of the first roller 1 and holes for supporting paired bearings 15 and 15 that rotatably support the shaft 2a, 2a of the second roller 2. The support plates 11a, 11b are made of a material having a coefficient of linear expansion substantially the same as that of the third and the fourth rollers 3, 4.

In this embodiment, the shaft 1a of the first roller 1 is integral with the input shaft a, and the shaft 2a of the second roller 2 is integral with the output shaft b. Thus, this embodiment constitutes a speed-reduction transmission.

The bearings 14a, 14b for the input side first roller are constructed as double-row bearings, while the bearings 15 for the output side second roller are constructed as single-row bearings.

Accordingly, since the bearings of the relatively weaker radial stiffness side are constructed as double-row bearings, the bearings 14a, 14b for the first roller and the bearings 15 for the second roller (i.e. the input side bearings and the output side bearings) have substantially the same

radial stiffness, and the transmission capacity can be increased.

Figs. 8A to 8C show a friction roller transmission (speed reduction transmission) according to a modification of the above-described embodiment of the present invention. Fig. 8A is a partly cut-away front view, Fig. 8B is a cross sectional view taken along line b-b in Fig. 8A, and Fig. 8C is a cross sectional view taken along line c-c in Fig. 8B.

In this modification, the bearings for the first roller are constructed as multiple-row or triple-row bearings 14a, 14b and 14c, and the bearings for the second roller are constructed as multiple-row or double-row bearings 15a, 15b.

Accordingly, in this modification also, since the bearings of the relatively weaker radial stiffness side are constructed as multiple-row bearings with the larger number of rows, the bearings 14a, 14b, 14c for the first roller and the bearings 15a, 15b for the second roller (i.e. the input side bearings and the output side bearings) have substantially the same radial stiffness, and the transmission capacity can be increased.

The bearings for the first roller and the bearings for the second roller are not limited to the triple-row bearings 14a, 14b, 14c and the double-row bearings 15a, 15b, but the number of rows of each

bearing may be increased in accordance with required radial stiffness.

In the embodiment shown in Figs. 3A to 7, the pair of support plates 11a, 11b support the bearings 14a, 14b and the bearings 15 that support the first and the second rollers 1, 2 respectively. These support plates 11 may be made of a material having a coefficient of linear expansion substantially the same as that of the third and the fourth rollers 3, 4.

Surfaces of the support plates 11a, 11b are used as sliding surfaces for the third and the fourth rollers 3, 4. In the case of conventional integral type housings, the bottom face of an opening for allowing insertion of the third and the fourth rollers 3, 4 serves as a sliding surface, and therefore, it is difficult to apply finish processing thereto. In contrast, in this embodiment, the two support plates 11a, 11b have a simple plate-like shape with the same thickness and the same shape. Accordingly, finish processing of the sliding surfaces can be easily carried out. Alternatively, the support plates 11a, 11b can be punched out using a press molding process or the like to eliminate the finish processing itself. In addition, they may be the same parts that are opposed to each other, a cost reduction can be achieved.

The third and the fourth rollers 3, 4 are held

by two holders 20, 20 with an offset. Each holder 20 is composed of a flange portion 21 having a nearly semicircular cross section and a shaft portion 22. The respective flange portions 21 and the shaft portions 22 of the two holders 20 are at the same height and horizontally offset from each other by a predetermined distance as will be seen from Fig. 3A. The third and the fourth rollers 3, 4 are rotatably supported on the shaft portions 22, 22 of the holders 20, 20 respectively by means of the bearings 23, 23.

Backup rollers 30, 30 that are in contact with the third and the fourth rollers 3, 4 respectively are provided to restrict displacement the third and the fourth rollers 3, 4 to a predetermined amount. Each backup roller 30 is, for example, a rolling bearing with an outer ring serving as the contact surface.

In this embodiment, displacement of the third and the fourth rollers 3, 4 is restricted to the predetermined amount by the backup rolling bearings 30 serving as backup rollers to avoid getting-over of the third and the fourth rollers 3, 4 and to prevent transmission of torques larger than a predetermined torque.

As shown in Figs. 3A to 5, the plate-like spacer 10 mentioned above is hollowed out to have a continuous space composed of a basically cylindrical

space Sa for housing only the first roller 1, a basically cylindrical space Sb for housing only the second roller 2, a basically cylindrical space Sc for housing only the third and the fourth rollers 3, 4 and basically cylindrical spaces Sd for housing only the backup rolling bearings 30, 30. The spaces Sd are large enough to allow positional adjustment of the rolling bearings 30 housed therein, as will be described later. The spaces Sd are spaces each having a bottom that open on opposite surfaces of the spacer 10 at symmetrical positions to back up the third and the fourth rollers 3, 4.

As per the above, in this embodiment, the plate-like spacer 10 is disposed between the pair of support plates 11a, 11b, so that the support plates 11a, 11b are fixed with a predetermined distance therebetween. By increasing the precision of the thickness of the plate-like spacer 10, it is possible to fix the distance between the pair of support plates 11a, 11b with a higher degree of accuracy.

In addition, since the aforementioned spaces Sa to Sd are formed continuously in the interior of the plate-like spacer 10, it is possible to reduce the volume of the interior space of the friction roller transmission as much as possible, and it is possible to prevent traction grease from scattering, reduce the consumption amount and the evaporation amount of

traction grease, and lengthen the life of traction grease.

As specifically shown in Figs. 6 and 7, a mounting bolt shaft 31 is fitted into and fixed to the inner ring of the backup rolling bearing 30.

In addition, in this embodiment, the mounting bolt shaft 31 is fixedly secured in a hole formed on each of the pair of support plates 11a, 11b by means of a nut 32. The head portion 31a of mounting bolt shaft 31 fitted in the inner ring of the backup rolling bearing 30 is eccentric to the shaft portion 31b by a predetermined amount on which male threads are formed.

In this embodiment, since in the mounting bolt shaft 31 for each of the support plate 11a, 11b, the head portion 31a attached to the backup rolling bearing 30 and the shaft portion 31b attached to the support plate 11a or 11b are eccentric to each other by a predetermined amount, the position of the backup rolling bearing 30 can be changed, by rotating the shaft portion 31b, on a circle with a radius equal to the amount of the eccentricity. The shaft portion 31b has a hexagonal hole 31c formed on the outer end thereof into which a tool is to be inserted to allow adjusting the rotational position of the mounting bolt shaft 31.

As per the above, the head portion 31a attached

to the backup rolling bearing 30 and the shaft portion 31b attached to the support plates 11a, 11b are eccentric to each other by a predetermined amount, and the position of the backup rolling bearing 30 can be adjusted by changing the phase of the mounting bolt shaft 31. Thus, it is possible to achieve the intended maximum transmissible torque in accordance with the radial stiffness of the bearings of the actual machine and to prevent failure of the transmission path due to excessive torque transmission from occurring.

The present invention is not limited to the above-described embodiment, but it may be modified in various ways. As described in the foregoing, in the friction roller transmission according to the present invention, backup bearings that are contact with the third and the fourth rollers for restricting displacement of the third and the fourth rollers to a predetermined amount are provided, wherein the position of the backup bearings can be adjusted. Therefore, it is possible to achieve the intended maximum transmissible torque and to prevent failure of the transmission path due to excessive torque transmission from occurring.